THE BALL IN PLAY DEMANDS OF ELITE RUGBY UNION

by

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Abstract

The purpose of this investigation was to quantify the competitive 'ball in play' (BIP) locomotive demands of elite rugby union and establish whether differences exist between overall match demands and those experienced during BIP. A total of 144 performances from eight English Premiership Clubs were tracked using global positioning systems (GPS) during 42 competitive matches (2010/11 season). Player positions were categorised in three ways: (1) Forwards and Backs; (2) Front Row, Second Row and Back Row Forwards, Scrumhalf, Inside and Outside Backs and (3) individual playing position (position numbers 1-15). Results indicated a number of significant ($P < 0.05$) differences between the Forwards and Backs including; the relative distances ($m \cdot min^{-1}$) and distributions (%) of the standing/walking, jogging and sprinting speed zones. The scrumhalf covered the greatest relative distance ($93.1\ m \cdot min^{-1}$), which was 44 % more than the lowest (Second Row). The tight head prop (1:20.7) illustrated the greatest mean work to rest ratio (WRR) whereas the lowest was identified for the loose head prop (1:4.7). Furthermore, the fly half demonstrated the greatest proportion of sprinting activities (1.4 % of total locomotion). Overall, the study provides insight into the BIP demands of rugby union, highlighting a greater percentage of high intensity (striding and sprinting) activities performed within a game than previously established. The findings demonstrate notable position-related differences and further reinforce the need for individualised player conditioning programmes.

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1. Introduction

Rugby union is an intermittent high-intensity sport, consisting of various facets demanding high levels of strength and power that are interspersed with periods of low intensity activity and rest (Cunniffe, Proctor, Baker & Davies, 2009). Since rugby union's emergence as a professional sport, researchers (Lacome, Piscione, Hager & Bourdin, 2013; Quarrie, Hopkins, Anthony & Gill, 2013; Austin, Gabbett & Jenkins, 2011; Cunniffe et al., 2009; Roberts, Trewartha, Higgitt, El-Abd and Stokes, 2008; Deutsch, Kearney & Rehrer, 2007; Eaton & George, 2006; Duthie, Pyne & Hooper, 2005) have aimed to quantify the sport's physical demands using methods such as time-motion analysis (TMA) or Global Positioning Systems (GPS). However, the majority of studies have been based upon a relatively small sample of matches (i.e. ≤ 16 full or part matches with data extrapolated to represent an 80 minute match).

Researchers have attempted to quantify the demands (e.g. distance travelled) of individual playing positions in order to better understand position specific physical and technical requirements to enable optimum athlete preparation. This has often been achieved through the grouping of Forwards and Backs (e.g. Cunniffe et al., 2009) and positional clustering such as; Front Row Forwards, Back Row Forwards, Inside Backs and Outside Backs (e.g. Venter, Opperman and Opperman, 2011). The results of these comparisons illustrate the Backs to consistently cover a greater total distance (~ 750 m) than the Forwards (Lacome et al., 2013; Quarrie et al., 2013; Cunniffe et al., 2009; Roberts et al., 2008). In contrast, Venter et al. (2011) extrapolated data from 60 minutes of semi-professional under-19 match-play identifying Forwards (Front Row) to cover the greatest distances (4672 m vs. 4302 m for the lowest) in comparison to the Back Row Forwards, Inside Backs and Outside Backs respectively. However, given a decrease in high intensity running was highlighted towards the latter stages of matches in rugby league (Sykes, Twist, Nicholas & Lamb, 2011), and soccer (Bradley et al., 2009), the extrapolation of data from match sections to provide a full match equivalent is clearly questionable.

More recently, the most comprehensive study to date (Cahill, Lamb, Worsfold, Headey & Murray, 2013), assessing the demands of professional rugby union included over 100 elite rugby players throughout 44 matches. Scrumhalves were identified as covering the greatest absolute distances per match (~ 7000 m), whilst the loose head prop covered the least (~ 4900 m). The scrumhalf also covered the greatest distance relative to playing time ($78.5\ m \cdot min^{-1}$), which was 26% greater than the lowest (tight head prop). Moreover, Lacome et al. (2013) analysed elite international players during the Six Nations identifying greater total distances than previous studies of 7944 m and 7006 m for Backs and Forwards respectively. International standard competition is the highest level in professional rugby and appears to place an increased level of physical and locomotive demand upon the players.

Speed and acceleration are important qualities in rugby (Baker & Nance, 1999), with good running speed over short distances fundamental to success (Sayers, 2000; Baker & Nance, 1999). Key aspects of the modern game such as covering in defence or breaking away during attacking play to score are related to these qualities. Super 12 rugby players sprint an average of 15 m (Forwards) and 20 m (Backs) on 13 and 24 occasions respectively (Duthie et al., 2005). Austin et al. (2011) identified an average of 40 sprints per match, which is significantly greater than the 18 reported by Duthie et al. (2005). Austin et al. (2011) suggested the increase to be the result of Super rugby becoming faster than it was previously in 2000/2001. Further, Austin et al. (2011) identified average sprint distances of 16 m, 14 m, 17 m and 18 m for Front Row Forwards, Back Row Forwards, Inside Backs and Outside Backs respectively. Within English rugby, Eaton and George (2006) reported an average of 4 sprints per match for Forwards (ranging 6 m to 9 m), while Backs sprinted 13 times (ranging 13 m to 15 m) a match.

Performance workload or physical demands can be quantified by the total (distance covered and/or time spent within various speed zones) and distribution of high (sprinting, cruising and rucking/mauling) and low (standing, walking or jogging) intensity work performed (Roberts et al., 2008). During a 70-minute match (age group match length), Forwards performed approximately three times more high-intensity work (11.2 min) than Backs (3.6 min) due to Front Row and Back Row forwards performing work more frequently (Deutsch, Maw, Jenkins & Reaburn, 1998). Front Row and Back Row Forwards' contact involvement (i.e. rucking, mauling and tackling) accounted for approximately 80-90% of their high-intensity work. Whereas approximately 60-70% of the high-intensity work performed by Inside and

Outside Backs involved cruising or sprinting activities (Deutsch et al., 2007). Furthermore, the time spent performing high- and low-intensity activity by Forwards (high 14%, low 86%) and Backs (high 6%, low 94%) in Super 12 rugby (Duthie et al., 2005) was similar to the results identified within Roberts et al. (2008) (Forwards: high 12%, low 88% and Backs: high 4%, low 96%). These small differences could be a reflection of the differing patterns of play within the northern and southern hemispheres, however, both studies support previous work describing the intermittent nature of rugby union whereby longer low-intensity periods are interspersed with short high-intensity work efforts.

Previous analyses of the intensity of players' movements in team sports have tended to quantify the distances covered within arbitrary pre-determined speed zones (e.g. Coughlan, Green, Pook, Toolan & O'Connor, 2011; Cunniffe et al., 2009). However, Cahill et al. (2013) suggest the peak speeds reached by various players and positions vary significantly, with some positions potentially unable to reach higher speeds often, if at all (due to the physical variations between rugby positions within the modern game). Duthie, Pyne and Hooper (2003) highlighted this issue by suggesting that speeds reached by Backs can be 37% greater than Forward players. It would therefore seem more appropriate to apply relative speed classifications based upon data collected across a season (e.g. method utilised by Cahill et al., 2013 and Venter et al., 2011). Utilising this method demonstrated English Premiership matches to be typically played at low speeds, with all positions covering at least 80% of their total distance at < 20% (standing/walking) or 20-

50% (jogging) of their maximum velocity (Vmax) (Cahill et al., 2013). In addition, hookers spend the highest proportion of any position (53.4%) in the 'jogging' speed zone, yet the least (8.9%) in the 'striding' (51-80%) zone (Cahill et al., 2013). Furthermore, the Backs covered greater distances walking than the Forwards, with the Outside Backs, particularly the full back, covering the greatest. Bompa and Claro (2009) suggested that while Forwards are engaged in intense activity, Backs are typically walking, standing, running in support play, covering in defence or repositioning based upon field position.

A work to rest ratio (WRR) provides a simple and objective means of indicating and quantifying the demand of intermittent team sports (Deutsch et al., 2007; Duthie et al., 2003). Duthie et al. (2005) and Eaton and George (2006) demonstrated Forwards (1:6 and 1.8) to have lower mean WRRs when compared to Backs (1:17 and 1:15). Furthermore, WRRs for the Front Row Forwards, Back Row Forwards, Inside Backs and Outside Backs were 1:7, 1:6, 1:15 and 1:21 respectively (Duthie et al., 2005). In contrast, Austin et al. (2011) identified similar WRRs for Front Row and Back Row Forwards (1:4 and 1:4) but considerable differences for Inside and Outside Backs (1:5 and 1:6) compared with Duthie et al. (2005). More recently, Lacome et al. (2013) analysed 30 French international players from 5 full Six Nations matches identifying mean WRRs of 1:7 and 1:9 for Forwards and Backs respectively. The aforementioned studies infer that rugby union at club level has become a more physically demanding sport, at least for the Backs, which is evidenced by the decrease in mean WRRs. Cunniffe et al. (2009) identified the third quarter to be the most intense as reflected in lower WRRs and an increase in relative ($m \cdot min^{-1}$) high intensity running. The decrease in WRR for the second half indicates there to be less recovery time between work bouts (Forwards: 1:5.7 vs. 1:4.8 and Backs: 1:5.1 vs. 1:4.7). However, it must be noted that one Back and one Forward player was analysed, therefore data presented may not be fully representative of all individualised Forward and Back positions.

Fatigue experienced during match play may be manifested in the amount of high-intensity activity performed during progressive time periods. Previous research within soccer has demonstrated a reduction in high intensity activity performed towards the conclusion of each half (Krustrup et al., 2006; Mohr, Krustrup, & Bangsbo, 2003). Total high-intensity running (m) travelled decreased significantly in the final 15 minutes of soccer match play compared to any other 15-minute section (Mohr et al., 2003). Furthermore, mean high and very high intensity running was significantly lower (~ 30% and ~ 45%) in the final quarter (Sykes et al., 2011; Sirotic, Coutts, Knowles & Catterick, 2009). When comparing match halves, rugby union has demonstrated limited differences in locomotive demands (e.g. exercise duration and WRRs) except mean acceleration observed, whereby a reduction was evident in the 2nd half (Lacome et al., 2013). However, Roberts et al. (2008) analysed successive 10-minute match periods revealing greater distances travelled in the first 10 minutes (838 m) compared with any period thereafter.

Separating a rugby union match into 10 or 15-minute sections to assess variations in locomotive demands represents a potentially flawed approach, in part, due to the duration of time the ball is 'out of play' (i.e. on average ~ 45-50 minutes). When comparing successive splits, the time the ball is in play may well vary significantly, thus impacting upon the identified locomotive demands. Due to the unreliable nature of presenting mean locomotive demands across fixed splits (i.e. 5 minute) and the full 80-minute match, it would therefore seem more appropriate to assess the demands of rugby union using locomotive data collected during 'ball in play' (BIP). Furthermore, the majority of the studies (except Cahill et al., 2013 and Quarrie et al., 2013) assessing the demands of rugby union have employed four positional groups (i.e. Front Row Forwards, Back Row Forwards, Inside Backs and Outside Backs). Given differences were identified between these positional groups it would appear logical to quantify and evaluate the various physical demands placed upon individual playing positions.

Therefore the aim of the study is twofold: (i) to quantify the competitive BIP locomotive demands of elite rugby union utilising GPS within the English Premiership and (ii) to establish whether differences exist between the demands of BIP and overall match analysis.

2. Methods

2.1 Participants and GPS data collection

A total of 120 elite male rugby players (age 27.5 + 4.2 years; body mass 103.8 + 12.6 kg; stature 1.87 + 0.07 m) who were members of 8 professional clubs from the English Premiership volunteered to participate within data collection. Each player wore a GPS unit (mass = 86 g; size = 0.8 x 0.4 x 0.2 cm) (SPI Pro, GPSports, Canberra, Australia) in a padded harness on match day that was positioned between the left and right scapulae. All participants were fully familiarised with the devices during training before competitive match play. The GPS devices captured data at a sampling frequency of 5 Hz and have previously been validated for measuring speed and distances within team sports (Waldron, Worsfold, Twist & Lamb, 2011). Following the completion of each match, the GPS data files were downloaded onto a personal computer for future analyses using Team AMS software (version 10; GPSports, Canberra, Australia). In total, 144 GPS files were collected from 42 Premiership matches throughout the 2010/11 season.

2.2 Design and player grouping

The study was developed as a descriptive independent groups design with participating players being grouped based upon their specific playing position (i.e. position number 1-15) during each analysed match. The participating players were grouped in three ways to allow comparisons to be made with current published research. Initially, players were grouped into Forwards (loose head prop, hooker, tight head prop, left lock, right lock, blind side flanker, open side flanker and number eight) or Backs (scrum half, fly half, left wing, inside centre, outside centre, right wing and the full back) and further grouped into six positional groups; Front Row Forwards (tight head prop, loose head prop and hooker), Second Row Forwards (left lock and right lock), Back Row Forwards (open side flanker, blindside flanker and number eight), Scrumhalf, Inside Backs (fly-half, inside centre and outside centre) and Outside Backs (left wing, right wing and full back) respectively. The Scrumhalf position remained separated from any of the other five positional groups due to the unique nature of the position as highlighted within previous research (e.g. Roberts et al., 2008). Furthermore, the players were categorised using their individual playing positions; loose head prop, hooker, tight head prop, left lock, right lock, blind side flanker, open side flanker, number eight, scrum half, fly half, left wing, inside centre, outside centre, right wing and the full back. All substitutions were assigned to one of the aforementioned 15 positions based upon the position they were substituted on to fulfill.

2.3 Procedures

Each of the 42 matches was firstly coded for BIP using SportsCode Elite (version 9.8; Sportstec, NSW, Australia). This process provided the various splits throughout the match where the ball was 'in play' and the players were able to compete for possession of the ball. The coded BIP splits were then exported into Microsoft Excel and converted into the appropriate software recognisable format (i.e. Greenwich Mean Time [GMT]). Each converted split was entered into the GPS software and subsequently applied to all players wearing the devices within that individual match. This process was repeated for all 42 matches and produced one GPS file per individual player for every match they participated within. Following the creation of the BIP specific GPS files within the software, each player file was exported into Excel in order to be assessed in relation to the study aims.

2.4 Locomotive variables

The relative distance ($m \cdot min^{-1}$; measured relative to time on the pitch) covered throughout total BIP, along with the relative distances ($m \cdot min^{-1}$) covered within various speed zones was quantified. The differentiating of speed zones was taken from the method utilised within Venter et al. (2011) and Cahill et al. (2013), where each zone was individualised to each player's maximum running speed (Vmax) attained throughout the season via the GPS devices. The five zones employed were; < 20% Vmax (standing and walking), 20-50% Vmax (jogging), 51-80% Vmax (striding), 81-95% Vmax (sprinting) and 96-100% Vmax (maximum sprint). Mean (i.e. dividing duration of rest: < 20% and 20-50% Vmax by the duration of work: 51-80%, 81-95% and 96-100% Vmax) and 'worst case' or minimum WRRs (i.e. lowest mean ratio from any given match for that individual position or positional grouping) were also formulated. All variables were assessed using data from BIP in an attempt to negate the underestimation of the in-play match demands when locomotive data is assessed and presented utilising total match time (i.e. 80 minutes). All variables are presented as mean ± standard deviation (SD) where appropriate.

2.5 Reliability

Intra- and inter-observer agreement in relation to the BIP duration was assessed using the percentage error (%Error) method advocated by Hughes, Cooper and Nevill (2004). The lead researcher assessed randomly selected matches on a test re-test basis, equivalent to 25% (n = 11) of the total matches analysed. A secondary analyst subsequently assessed the same matches to enable inter-observer reliability assessments to be conducted. Percentage error was identified as < 5% for BIP duration throughout all matches analysed (Table 1.), therefore the researcher was confident of consistent and reliable coding throughout.

Table 1. Intra- and inter-observer reliability analysis for ball in play duration.

Match Number	Intra-Observer - %Error	Inter-Observer - %Error
1	2.2	2.9
2	1.7	2.2
3	1.3	3.2
4	1.1	1.8
5	0.8	1.0
6	2.1	3.3
7	0.8	2.2
8	0.6	0.9
9	0.5	1.1
10	2.0	1.8
11	0.6	4.4
Mean	1.3	2.3

2.6 Statistical analyses

Comparisons across the analysed dependent variables were made in order to identify potential differences between the demands of the various playing positions during BIP. Initially, diagnostic tests (Shapiro-WIlk and Levene) were performed on the distributions of the dependent variables to check the assumptions of normality and homogeneity of variance. The variables were identified as non-normally distributed ($P < 0.05$), therefore a series of Mann Whitney U and Kruskal-Wallis tests were employed to compare all variables between Forwards and Backs, and the six pre-defined positional groups. If required, post hoc Mann Whitney U tests were utilised to identify statistical differences between groups. Boferroni adjustments were applied to the alpha level ($P < 0.05$) in order to offset the risk of a type I error occurring due to multiplicity testing. All statistical analysis was performed using SPSS V21 (SPSS Inc, 2010).

3. Results

3.1 Forwards and Backs positional groups

The Backs covered a significantly (P < 0.05) greater relative distance in comparison to the Forward players (75.4 vs. 67.5 m $\cdot$ min^{-1}) (Table 2.). The Forwards and Backs covered the majority of their movement at low intensity, with the standing/walking and jogging zones equating to 86.8% and 87.2% respectively. The Forwards' distance was predominantly covered within the jogging zone (46.2%) whereas standing/walking (46.7%) was the predominant zone for the Backs. The average WRR for each group was similar with Forwards (1:6.6) demonstrating a marginally lower WRR than the Backs (1:6.8). Furthermore, the 'worst case' WRR between the two groups were also similar (1:2.3 vs. 1:3.0). A number of differences between the Forwards and Backs were identified as significant (P < 0.05) including; the relative distances (m $\cdot$ min^{-1}) and distributions (%) of the standing/walking, jogging and sprinting speed zones.

Table 2. Comparison of Forwards and Backs for all analysed variables.

	Forwards (n = 74)		**Backs (n = 70)**	
Variables	Mean	SD	Mean	SD
Relative total distance ($m \cdot min^{-1}$)	67.5*	14.9	75.4	15.3
WRR	1:6.6	-	1:6.8	-
Worst case WRR	1:2.3	-	1:3.0	-
RD < 20% Vmax ($m \cdot min^{-1}$)	27.4*	4.5	35.0	5.4
RD < 20 - 50% Vmax ($m \cdot min^{-1}$)	31.2*	9.5	30.7	8.6
RD < 51 - 80% Vmax ($m \cdot min^{-1}$)	8.6	4.9	9.2	3.9
RD < 81 - 95% Vmax ($m \cdot min^{-1}$)	0.3*	0.6	0.6	0.6
RD < 96 - 100% Vmax ($m \cdot min^{-1}$)	0.0	0.1	0.0	0.1
High intensity movement (%)	13.2	5.1	12.8	4.3
Low intensity movement (%)	86.8	5.1	87.2	4.3
RD < 20% Vmax (%)	40.6*	7.7	46.7	6.4
RD < 20 - 50% Vmax (%)	46.2*	5.6	40.5	5.2
RD < 51 - 80% Vmax (%)	12.7	4.8	12.0	4.1
RD < 81 - 95% Vmax (%)	0.5*	0.7	0.7	0.7
RD < 96 - 100% Vmax (%)	0.0	0.1	0.0	0.1

*Significantly different ($P < 0.05$) from the Backs. WRR = Work Rest Ratio. RD = Relative Distance. SD = Standard Deviation. n = number of performances sampled.

3.2 Six positional groups.

Initial analysis in relation to the six positional groups (Table 3.) identified significant differences ($P < 0.008$) within 7/15 locomotive variables. Post- hoc analyses identified the Scrumhalf to record the greatest relative distance (93.1 $m \cdot min^{-1}$) in comparison to all other positional groups. The relative distance travelled by the Scrumhalf was 28.5 $m \cdot min^{-1}$ (44 %) greater than the lowest (Second Row: 64.6 $m \cdot min^{-1}$). Furthermore, the Scrumhalf covered ~ 29 % more distance ($m \cdot min^{-1}$) within the striding speed zone in comparison to any other positional group and ~ 78 % more than the Front Row Forwards (i.e. the lowest).

The Outside Backs covered ~ 50 % (49.4 %) of their movement within the standing/walking speed zone, which was significantly (P < 0.008) more than the Front Row, Second Row and Back Row Forwards. However, the Outside Backs (38.0 %) covered the smallest proportion of movement within the jogging speed zone compared to all other positional groups. This movement distribution was significantly less than that of the Front Row (48.0 %), Second Row (46.5 %) and Back Row (44.2 %) Forwards respectively (P < 0.008). The Inside and Outside Backs illustrated similar results for all locomotive variables and no statistically different results were identified between any of the Forward groups. However, it is noteworthy that the lowest and highest identified WRRs for the six positional groups can be observed between two of the Forward sub groups (i.e. Back Row = 1:5.6 vs. Front Row = 1:7.7).

Table 3. Comparison of the six positional groups for all analysed variables.

Variables	**Front row[1] (n = 30)**		**Second row[2] (n = 20)**		**Back row[3] (n = 24)**		**Scrumhalf[4] (n = 10)**		**Inside backs[5] (n = 30)**		**Outside backs[6] (n = 30)**	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Relative total distance ($m \cdot min^{-1}$)	66.8	15.7	64.6	17.5	70.7	12.4	93.1	13.4	74.3	12.1	72.4	15.0
WRR	1:7.7	-	1:6.5	-	1:5.6	-	1:6.0	-	1:6.8	-	1:6.9	-
Worst case WRR	1:2.3	-	1:3.9	-	1:2.5	-	1:4.0	-	1:3.0	-	1:3.9	-
RD < 20% Vmax ($m \cdot min^{-1}$)	$27.1^{*5,6}$	4.4	$25.9^{*5,6}$	6.6	$28.8^{*5,6}$	3.1	39.8	5.6	33.4	3.5	35.4	6.1
RD < 20-50% Vmax ($m \cdot min^{-1}$)	32.0	10.5	30.1	9.3	31.2	8.8	40.0	8.7	31.4	6.7	27.9	8.3
RD < 51-80% Vmax ($m \cdot min^{-1}$)	7.4	6.0	8.3	3.9	10.2	4.4	13.2	3.2	8.9	3.2	8.4	3.8
RD < 81-95% Vmax ($m \cdot min^{-1}$)	0.2^{*6}	0.6	0.3^{*6}	0.5	0.4	0.5	$0.1^{*5,6}$	0.2	0.5	0.3	0.7	0.8
RD < 96-100% Vmax ($m \cdot min^{-1}$)	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0
High intensity movement (%)	11.6	6.4	13.4	4.3	14.8	4.4	14.4	3.8	12.5	4.2	12.6	4.6
Low intensity movement (%)	88.4	6.4	86.6	4.3	85.2	4.4	85.6	3.8	87.5	4.2	87.4	4.6
RD < 20% Vmax (%)	40.4^{*6}	9.4	$40.1^{*5,6}$	5.8	41.0^{*6}	7.2	42.7	7.4	45.4	6.7	49.4	5.6
RD < 20-50% Vmax (%)	$48.0^{*5,6}$	5.9	$46.5^{*5,6}$	4.1	44.2^{*6}	6.2	42.9	5.9	42.1	4.8	38.0	5.3
RD < 51-80% Vmax (%)	11.2	5.9	12.8	3.9	$14.2^{*5,6}$	4.1	14.2	3.8	11.8	3.9	11.6	4.5
RD < 81-95% Vmax (%)	0.3	0.7	0.5	0.6	0.5^{*4}	0.7	$0.2^{*5,6}$	0.3	0.7	0.5	1.0	1.0
RD < 96-100% Vmax (%)	0.1	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.1

Note: $^{*(n)}$ = Significantly different ($P < 0.008$) from the group number within superscript for the corresponding locomotive variable. WRR = Work Rest Ratio. RD = Relative Distance. SD = Standard Deviation. *n* = number of performances sampled.

3.3 Fifteen individual positional groups

All individual positional groups (Table 4, 5 and 6) were observed to cover in excess of 64 m $\cdot$ min^{-1} with the exception of the tight-head prop (58.8 m $\cdot$ min^{-1}). Furthermore, the scrumhalf (93.1 m $\cdot$ min^{-1}) covered at least 14.3 m $\cdot$ min^{-1} (18 %) more relative distance than any other position (ahead of the fly half: 78.8 m $\cdot$ min^{-1}) and 34.3 m $\cdot$ min^{-1} (58 %) more than the position covering the least (tight head prop). The greatest mean WRR was observed within the tight head prop group (1:20.7), which was almost two times that of the outside centre (1:10.4). Notably however, the WRR of the tight head prop was > 4 times the magnitude of the smallest (1:4.7) highlighted within the loose head prop group. Similar WRRs were identified between the lock (left: 1:6.5 vs. right: 1:6.5) and flanker (blindside: 1:5.7 vs. openside: 1:5.3) positions. Further notable similarities, with regards to positional WRRs, were observed between the hooker (1:7.0) and full back (1:7.0) positions.

All positions, with the exception of the tight head prop (95.4 %) and the outside centre (91.3 %) covered 82-89 % of their total movement at low intensity. The majority of the Forward players (7/8) covered the highest proportion of their movement during jogging, whereas 5/7 of the Back positions covered the majority their movement within the standing/walking speed zone. The loose head prop (17.3 %) spent the greatest proportion of total relative distance within the striding speed zone and the least within the standing/walking (34.4 %) speed zone. The right (50.7 %) and left (52.6 %) wing positions performed the highest proportion of their locomotion during standing/walking but the lowest within the jogging speed zone (35.6 and 35.8 %). Furthermore, the fly half illustrated the greatest proportion of total sprinting activities (1.4 %) in comparison to all other positions.

Table 4. Comparison of the loose head prop, hooker, tight head prop, left lock and right lock for all analysed variables.

Variables	Loose-head Prop (*n* = 10)		Hooker (*n* = 10)		Tight-head Prop (*n* = 10)		Left Lock (*n* = 10)		Right Lock (*n* = 10)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Relative total distance ($m \cdot min^{-1}$)	67.2	17.1	77.2	15.6	58.8	14.4	64.4	12.9	64.9	22.1
WRR	1:4.7	-	1:7.0	-	1:20.7	-	1:6.5	-	1:6.5	-
Worst case WRR	1:2.8	-	1:2.6	-	1:2.3	-	1:5.2	-	1:3.9	-
RD < 20% Vmax ($m \cdot min^{-1}$)	23.1	3.0	28.2	3.1	29.8	7.2	25.9	3.1	26.0	10.1
RD < 20 - 50% Vmax ($m \cdot min^{-1}$)	32.3	11.7	39.4	9.3	26.4	10.6	29.9	8.1	30.3	10.1
RD < 51 - 80% Vmax ($m \cdot min^{-1}$)	11.6	6.0	9.2	6.3	2.6	5.7	8.5	2.8	8.1	5.1
RD < 81 - 95% Vmax ($m \cdot min^{-1}$)	0.2	0.4	0.4	1.0	0.1	0.3	0.2	0.3	0.5	0.8
RD < 96 - 100% Vmax ($m \cdot min^{-1}$)	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0
High intensity distribution (%)	17.6	4.5	12.5	6.0	4.6	8.7	13.4	2.7	13.3	5.8
Low intensity distribution (%)	82.4	4.5	87.5	6.0	95.4	8.7	86.6	2.7	86.7	5.8
RD < 20% Vmax (%)	34.4	8.7	36.5	7.3	50.6	12.1	40.2	5.3	40.0	6.2
RD < 20 - 50% Vmax (%)	48.0	6.3	51.0	4.4	44.8	6.9	46.4	4.3	46.7	4.0
RD < 51 - 80% Vmax (%)	17.3	4.5	12.0	5.1	4.4	8.1	13.2	2.7	12.5	5.2
RD < 81 - 95% Vmax (%)	0.3	0.7	0.4	0.9	0.2	0.5	0.2	0.4	0.8	0.8
RD < 96 - 100% Vmax (%)	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0

WRR = Work Rest Ratio. RD = Relative Distance. SD = Standard Deviation. *n* = number of performances sampled.

Table 5. Comparison of the blindside flanker, openside flanker, number eight, scrumhalf and fly half for all analysed variables.

Variables	**Blindside Flanker (*n* = 10)**		**Openside Flanker (*n* = 10)**		**Number Eight (*n* = 4)**		**Scrumhalf (*n* = 10)**		**Fly Half (*n* = 10)**	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Relative total distance ($m \cdot min^{-1}$)	69.3	15.3	74.1	15.5	66.2	6.4	93.1	13.4	78.8	20.1
WRR	1:5.7	-	1:5.3	-	1:6.4	-	1:6.0	-	1:4.9	-
Worst case WRR	1:3.7	-	1:2.5	-	1:4.6	-	1:4.0	-	1:3.0	-
RD < 20% Vmax ($m \cdot min^{-1}$)	27.8	3.2	30.3	2.4	27.8	3.8	39.8	5.6	31.3	6.3
RD < 20 - 50% Vmax ($m \cdot min^{-1}$)	31.1	11.5	32.1	10.1	29.5	4.7	40.0	8.7	34.2	9.8
RD < 51 - 80% Vmax ($m \cdot min^{-1}$)	10.1	4.0	11.2	6.4	8.5	3.0	13.2	3.2	12.2	6.0
RD < 81 - 95% Vmax ($m \cdot min^{-1}$)	0.3	0.6	0.4	0.7	0.4	0.3	0.1	0.2	1.1	0.7
RD < 96 - 100% Vmax ($m \cdot min^{-1}$)	0.0	0.0	0.1	0.2	0.0	0.1	0.0	0.1	0.1	0.2
High intensity movement (%)	15.0	4.2	15.8	5.3	13.6	3.8	14.4	3.8	16.9	5.3
Low intensity movement (%)	85.0	4.2	84.2	5.3	86.4	3.8	85.6	3.8	83.1	5.3
RD < 20% Vmax (%)	40.1	8.7	40.9	7.7	41.9	5.1	42.7	7.4	39.7	6.5
RD < 20 - 50% Vmax (%)	44.8	8.1	43.3	5.1	44.5	5.5	42.9	5.9	43.4	5.5
RD < 51 - 80% Vmax (%)	14.5	3.8	15.1	4.8	12.9	3.8	14.2	3.8	15.4	4.7
RD < 81 - 95% Vmax (%)	0.5	0.7	0.6	0.9	0.7	0.4	0.1	0.3	1.3	0.7
RD < 96 - 100% Vmax (%)	0.0	0.0	0.1	0.3	0.1	0.1	0.1	0.1	0.1	0.2

WRR = Work Rest Ratio. RD = Relative Distance. SD = Standard Deviation. *n* = number of performances sampled.

Table 6. Comparison of the left wing, inside centre, outside centre, right wing and full back for all analysed variables.

Variables	**Left Wing (*n* = 10)**		**Inside Centre (*n* = 10)**		**Outside Centre (*n* = 10)**		**Right Wing (*n* = 10)**		**Full Back (*n* = 10)**	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Relative total distance ($m \cdot min^{-1}$)	68.3	17.1	75.9	14.9	67.8	13.5	70.5	14.6	77.1	13.3
WRR	1:7.7	-	1:7.5	-	1:10.4	-	1:6.3	-	1:7.0	-
Worst case WRR	1:5.3	-	1:5.0	-	1:5.4	-	1:4.3	-	1:3.9	-
RD < 20% Vmax ($m \cdot min^{-1}$)	35.9	8.5	34.4	3.9	34.7	3.8	35.8	4.6	34.6	5.1
RD < 20 - 50% Vmax ($m \cdot min^{-1}$)	24.4	6.5	32.6	9.0	27.2	8.0	25.1	8.5	32.9	9.9
RD < 51 - 80% Vmax ($m \cdot min^{-1}$)	7.3	3.1	8.8	3.6	5.7	3.2	9.0	4.1	8.8	4.1
RD < 81 - 95% Vmax ($m \cdot min^{-1}$)	0.6	0.5	0.2	0.3	0.3	0.5	0.7	1.1	0.8	0.7
RD < 96 - 100% Vmax ($m \cdot min^{-1}$)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
High intensity movement (%)	11.6	4.8	11.8	4.0	8.8	3.2	13.7	4.1	12.4	5.0
Low intensity movement (%)	88.4	4.8	88.2	4.0	91.2	3.2	86.3	4.1	87.6	5.0
RD < 20% Vmax (%)	52.6	3.2	45.3	7.3	51.1	6.4	50.7	6.3	44.9	7.4
RD < 20 - 50% Vmax (%)	35.8	4.1	42.9	5.3	40.1	3.7	35.6	5.3	42.7	6.5
RD < 51 - 80% Vmax (%)	10.6	4.4	11.5	3.9	8.3	2.9	12.7	4.7	11.4	4.4
RD < 81 - 95% Vmax (%)	0.9	0.7	0.3	0.3	0.4	0.6	1.0	1.5	0.9	0.9
RD < 96 - 100% Vmax (%)	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.1

WRR = Work Rest Ratio. RD = Relative Distance. SD = Standard Deviation. *n* = number of performances sampled.

4. Discussion

The purpose of the current study was to quantify the BIP locomotive demands of elite rugby union utilising GPS within the English Premiership and establish whether differences exist between the demands of BIP and overall match analysis. This was achieved through the collection of locomotive data using previously validated 5 Hz GPS units (GPSports) during periods of BIP. The data presented herein contributed to the most comprehensive study to date (performances analysed on an overall and per position/positional grouping basis) quantifying the BIP locomotive demands of elite rugby union using GPS. The most significant findings of the current study pertain to the clear positional differences identified within the three grouping categorisations assessed (i.e. Forwards and Backs; six positional groups and the fifteen individual playing positions). These differences were clearly evident for the mean WRRs and relative distances ($m \cdot min^{-1}$) covered.

In accordance with previous research (Cahill et al., 2013; Lacome et al., 2013; Quarrie et al., 2013; Cunniffe et al., 2009; Roberts et al., 2008), the Backs (2821 m) were identified as covering a greater total distance than Forward (2524 m) players. The identified distances herein are considerably less than previous research, however, this can be attributed the studies quantifying the overall match demands in contrast to those experienced during BIP. Quarrie et al. (2013) presented data from international competition during periods of BIP using semi-automated TMA. The study highlighted greater absolute distances by Forwards (3788 m) and Backs (4100 m) in comparison to the current study. As previously eluded to, international standard represents the highest level of competition within rugby union and would appear to explain the differences between the comparative standards (English top tier club rugby vs. international). Furthermore, the Forwards (67.5 $m \cdot min^{-1}$) and Backs (75.4 $m \cdot min^{-1}$) covered a greater relative distance compared to the Forwards (66.7 and 64.6 $m \cdot min^{-1}$) and Backs (71.9 and 71.1 $m \cdot min^{-1}$) within Cunniffe et al. (2009) and Cahill et al. (2013) respectively.

The various positions within rugby union all have individualised roles within the modern game (e.g. hooker's lineout throwing or scrumhalf's ball distribution), therefore it was assumed that the in play locomotive demands would also vary significantly. Most notably, when positions are considered on an individual basis, the scrumhalf was the only position to cover in excess of 80 $m \cdot min^{-1}$ (93.1) which is a significant increase to the scrumhalf (78.5 $m \cdot min^{-1}$) data presented by Cahill et al. (2013). The heightened relative distance in comparison to all other positions may well be attributed to the role of the position itself, more specifically, the demands of keeping up with play and redistributing the ball following rucks and mauls. Moreover, there was considerable difference between the highest (scrumhalf: 93.1 $m \cdot min^{-1}$) and lowest (tight head prop: 58.8 $m \cdot min^{-1}$) observed relative distances. This finding clearly highlights the varying positional locomotive demands and further reinforces the need for differentiation within conditioning programmes in order to successfully prepare athletes for performance within the English Premiership.

The aforementioned issues regarding pre-determined speed zones were negated using relative speed classifications based upon an individual's maximum speed achieved throughout a season. Accordingly, it was observed that Premiership matches during BIP are played typically at low intensity, with all positions performing at least 82% of their locomotion within the standing/walking (< 20% Vmax) and jogging (20-50% Vmax) speed zones. The analysis of Forward's high (13.2 %) and low-intensity (86.8 %) distribution presented similar results to the work of Duthie et al. (2005) and Roberts et al. (2008). However, clear differences were evident between the Backs (Low: 87.2 %, High: 12.8 %) presented herein and the results of Duthie et al. (2005) (Low: 94 %, High 6 %) and Roberts et al. (2008) (Low: 96 %, High 4 %). Furthermore, the loose head prop (17.6 %) performed the highest percentage of high-intensity locomotion of all positions, whereas the tight head prop (4.6 %) performed the least. The aforementioned comparison provides evidence of the differing positional demands within the sport, whereby two positions (tight and loose head props) similar in tactical location (scrum and team formation) demonstrate vast differences for the distributions of high- and low-intensity work performed.

The fly half demonstrated the highest proportion of sprinting activities (1.4 %) ahead of the two wing positions (left wing: 1.0 % and right wing: 1.0 %), which may appear surprising given the demands associated with the position itself. The fly half is more responsible for initiating and building attacks with their passing and kicking distribution in contrast to being the primary sprinting position within a team. These findings clearly indicate that rugby union players as part of a positional clustering and on an individual basis spend a significantly greater percentage of match involvement performing high intensity (striding and sprinting) activities than previously established.

To determine the physical demand of rugby union the study provided mean WRRs illustrating Forwards (1:6.6) to have similar WRRs (1:6 and 1:8) to Duthie et al. (2005) and Eaton and George (2006) respectively. Moreover, Backs (1:6.8) performed work more often than the respective studies (1:17 and 1:15) as demonstrated by the lower WRRs. However, Austin et al. (2011) identified similar WRRs for Backs (1:6) in comparison to those presented herein. The aforementioned findings may be explained by the sport becoming more physically demanding within recent years. Austin et al. (2011) suggested that a quicker ball distribution to the Backs and/or a change in tactical approach within elite match-play may explain the lower WRRs, however, the study's novelty and therefore differences in methodology (quantification of BIP vs. overall match demands) may be considered the primary explanation.

To the researcher's knowledge, the quantification of WRRs specific to individual rugby union positions has yet to be established, on an overall match and/or BIP basis, and therefore presents a further novel aspect of the current study. There were clear differences between positional WRRs (Table 3, 4 and 5), with the two prop positions (tight head and loose head) illustrating the highest (1:20.7) and lowest (1:4.7) values. This finding appears to confirm the need for individualised positional locomotive assessment and conditioning, however in contrast, the lock positions (right and left) elicit identical WRR values (1:6.5). Furthermore, the similarities between the hooker (1:7.0) and full back (1:7.0) positions suggest similar locomotive demand. Given the difference in positional roles (e.g. lineout throwing and scrimmaging), which inevitably contribute to an athlete's positional play and would be required within any conditioning simulation, may prevent the grouping of such positions based on WRRs alone.

A potential criticism of the current research pertains to the GPS devices utilised, despite being shown to be both valid and reliable (Waldron et al., 2011), technological advancements have enabled devices with an increased sampling frequency (e.g. 10 Hz) to be developed. It could be argued that an increase in sampling frequency (i.e. > 5 Hz), due to the number of data samples collected per second, may provide an increase in device validity when collecting locomotive data within team sports. Johnston, Watsford, Pine, Spurrs and Sporri (2013) supported this hypothesis, however in contrast; Johnston, Watsford, Kelly, Pine and Spurrs (2014) provide evidence that 15 Hz devices demonstrate lower validity than 10 Hz devices. Therefore caution should be undertaken when proposing to collate such data using GPS devices of greater sampling frequency than the 5 Hz units utilised herein. Furthermore, the study failed to quantify the technical aspects of rugby union such as key performance indicators (KPIs) (e.g. number of passes and tackles), which inevitably contribute to the sporting demands experienced by the players in game.

The current study provides a simple framework to assist in the quantification of the BIP demands of similar intermittent team sports such as rugby league or football. Furthermore, Lacome et al. (2013) assessed the overall locomotive demands during international competitive matches using TMA, identifying greater total distances than in previous studies. Therefore, it appears logical to further assess international rugby union during BIP utilising GPS devices. This type of analysis would highlight the locomotive variations between top tier club and international rugby union and therefore demonstrate the required locomotive conditioning. Moreover, studies should aim to introduce technical analyses, such as KPIs (e.g. tackles, passes etc.) or focus upon player impact data (e.g. endured tackle forces) and combine these collectively with the aforementioned locomotive demands in order to provide a more comprehensive assessment of rugby union.

As previously established, rugby union is an intermittent sport whereby longer low-intensity periods and rest are interspersed with short high-intensity work efforts. The current study is the first of its kind to quantify the locomotive BIP demands of elite male rugby union utilising GPS on an individualised positional basis within the English Premiership. The data presented herein demonstrates an increased locomotive demand (e.g. an increased relative distance and a subsequent decrease in WRRs) than previous research. There was a greater proportion of high intensity work (i.e. striding, sprinting and maximal sprinting) performed during BIP compared to the overall match (80 minutes) demands widely established within current published research.

Conditioning programmes should therefore aim to re-evaluate the distribution of high- and low-intensity work and incorporate a greater percentage of high intensity activities in order to reflect the current in play locomotive demands established herein. Overall, the current findings will enable practitioners to successfully develop player conditioning and rehabilitation programmes specific to the BIP demands of individualised positions within English rugby union.

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6. Appendices

1. Ethical Approval Certificate
2. Raw Data Disc Cover Sheet
3. Supervisory Contact

Appendix 1

Ethical Approval Certificate

Faculty of Life Sciences
Research Ethics Committee

frec@chester.ac.uk

Scott Nicholls
Market Drayton
Shropshire

17th September 2014

Dear Scott,

Study title: **Ball play in match demands of elite Rugby Union.**

FREC reference: **953/14/SN/SES**
Version number: **1**

Thank you for sending your application to the Faculty of Life Sciences Research Ethics Committee for review.

I am pleased to confirm ethical approval for the above research, provided that you comply with the conditions set out in the attached document, and adhere to the processes described in your application form and supporting documentation.

The final list of documents reviewed and approved by the Committee is as follows:

Document	Version	Date
Application Form	1	June 2014
Appendix 1 – List of References	1	June 2014
Appendix 2 – C.V. for Lead Researcher	1	June 2014
Appendix 3 – Written Permission, Nicola Finnigan	1	June 2014
Response to FREC request for further information or clarification		September 2014
Appendix 1 – Email confirmation, Dr. Paul Worsfold, University of Chester	1	September 2014

Please note that this approval is given in accordance with the requirements of English law only. For research taking place wholly or partly within other jurisdictions (including Wales, Scotland and Northern Ireland), you should seek further advice from the Committee Chair / Secretary or the Research and Knowledge Transfer Office and may need additional approval from the appropriate agencies in the country (or countries) in which the research will take place.

With the Committee's best wishes for the success of this project.

Yours sincerely,

Dr. Stephen Fallows
Chair, Faculty Research Ethics Committee

Enclosures: Standard conditions of approval.

Cc. Supervisor/FREC Representative

Appendix 2

Raw Data Disc Cover Sheet

1. Ball In Play Folder

    1.1 - Split Times For GPS Software

    1.2 - GPS Match Session Start Times

2. Data Folder

    2.1 - Participating Player Details

    2.2 - Individual Position GPS Export

3. Reliability

    3.1 - Ball In Play Template

    3.2 - Game 1 - 11 Ball In Play SportsCode Timelines

    3.3 - Ball In Play Reliability Analysis

4. Results And SPSS

    4.1 - Central Database GPS Export And Data Analysis

    4.2 - SPSS Raw Data

    4.3 - SPSS Normality Test Output

    4.4 - SPSS Forwards Vs Backs Mann Whitney U Test Output

    4.5 - SPSS Six Positional Groups Kruskal Wallis Test Output

    4.6 - SPSS Six Positional Groups Mann Whitney U Test Output

Appendix 3

Supervisory Contact

October

Nicola Finnigan: Development of first idea (later changed)

December

Nicola Finnigan: Development of second idea (current project)

January

Nicola Finnigan: Initial ball in play analysis attempt

Nicola Finnigan: Given a quarter of the ball in play times

February

Nicola Finnigan: Given the remainder of the ball in play times

Nicola Finnigan: Literature review, aim confirmation and GPS software demonstration

April

Nicola Finnigan: GPS data input update 1

Nicola Finnigan: GPS data input update 2

May

Nicola Finnigan: Sent my proposal/miscellaneous

Paul Worsfold: Ethics draft

June

Nicola Finnigan: Ethical approval related

Paul Worsfold: Ethical approval related

August

Paul Worsfold: Ethical approval issue/clarifying points for FREC

September

Nicola Finnigan: General update

Paul Worsfold: Sent introduction and methods for feedback

Paul Worsfold: Sent results for feedback